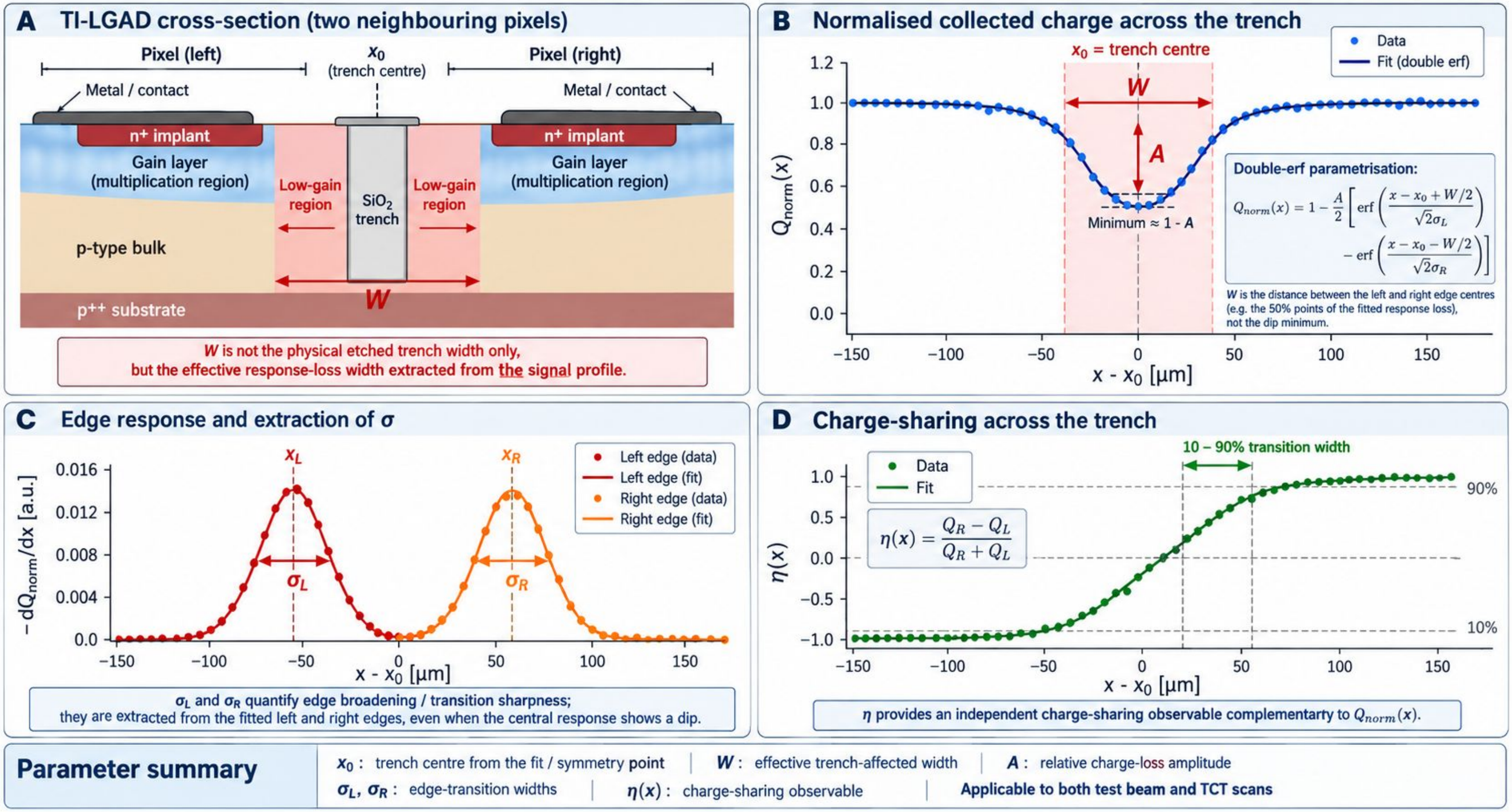
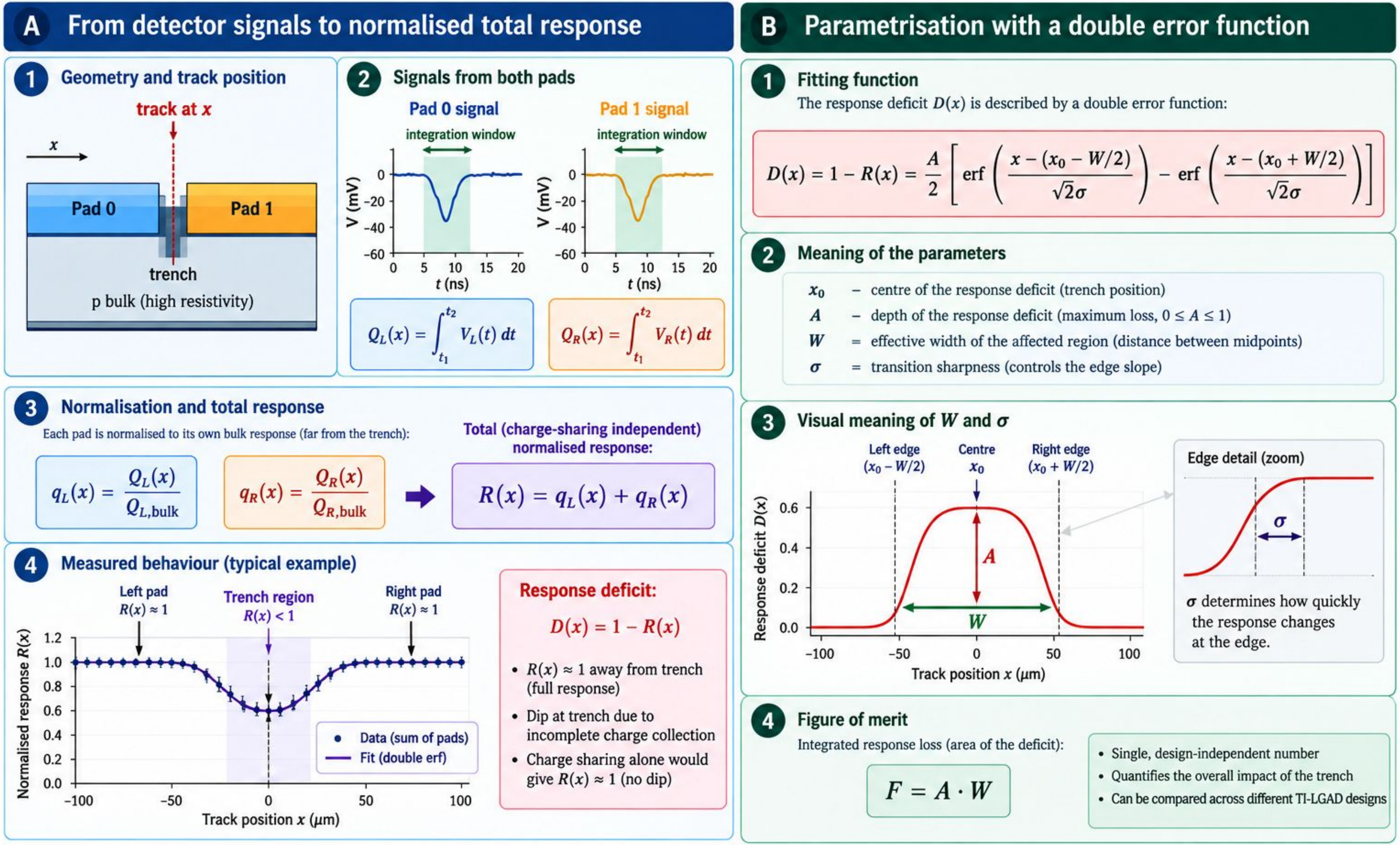
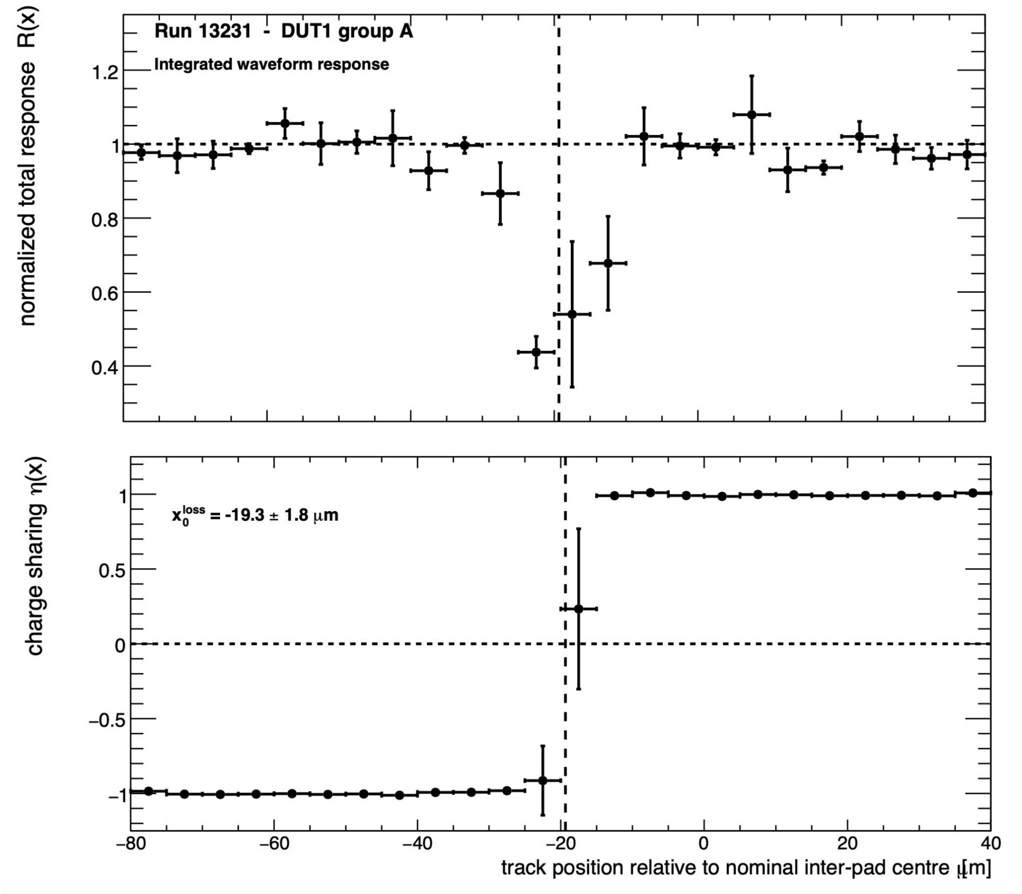
Conceptual parametrisation of TI-LGAD trench response




A From detector signals to normalised total response
1 Geometry and track position
track at x
x
Pad 0
Pad 1
trench
p bulk (high resistivity)
2 Signals from both pads
Pad 0 signal
Pad 1 signal
integration window
integration window
V (mV)
t (ns)
$Q_L(x) = \int_{t_1}^{t_2} V_L(t)\,dt$
$Q_R(x) = \int_{t_1}^{t_2} V_R(t)\,dt$
3 Normalisation and total response
Each pad is normalised to its own bulk response (far from the trench):
$q_L(x) = \frac{Q_L(x)}{Q_{L,\mathrm{bulk}}}$
$q_R(x) = \frac{Q_R(x)}{Q_{R,\mathrm{bulk}}}$
Total (charge-sharing independent) normalised response:
$R(x) = q_L(x) + q_R(x)$
4 Measured behaviour (typical example)
Left pad $R(x) \approx 1$
Trench region $R(x) < 1$
Right pad $R(x) \approx 1$
Normalised response $R(x)$
Track position x (μm)
Data (sum of pads)
Fit (double erf)
Response deficit:
$D(x) = 1 - R(x)$
• $R(x) \approx 1$ away from trench (full response)
• Dip at trench due to incomplete charge collection
• Charge sharing alone would give $R(x) \approx 1$ (no dip)
B Parametrisation with a double error function
1 Fitting function
The response deficit $D(x)$ is described by a double error function:
$D(x) = 1 - R(x) = \frac{A}{2}\left[\mathrm{erf}\left(\frac{x-(x_0-W/2)}{\sqrt{2}\sigma}\right) - \mathrm{erf}\left(\frac{x-(x_0+W/2)}{\sqrt{2}\sigma}\right)\right]$
2 Meaning of the parameters
x_0 – centre of the response deficit (trench position)
A – depth of the response deficit (maximum loss, $0 \leq A \leq 1$)
W = effective width of the affected region (distance between midpoints)
σ = transition sharpness (controls the edge slope)
3 Visual meaning of W and σ
Left edge ($x_0 - W/2$)
Centre x_0
Right edge ($x_0 + W/2$)
Response deficit $D(x)$
Track position x (μm)
Edge detail (zoom)
σ determines how quickly the response changes at the edge.
4 Figure of merit
Integrated response loss (area of the deficit):
$F = A \cdot W$
• Single, design-independent number
• Quantifies the overall impact of the trench
• Can be compared across different TI-LGAD designs

Testing the concept for wafer 5 (I)



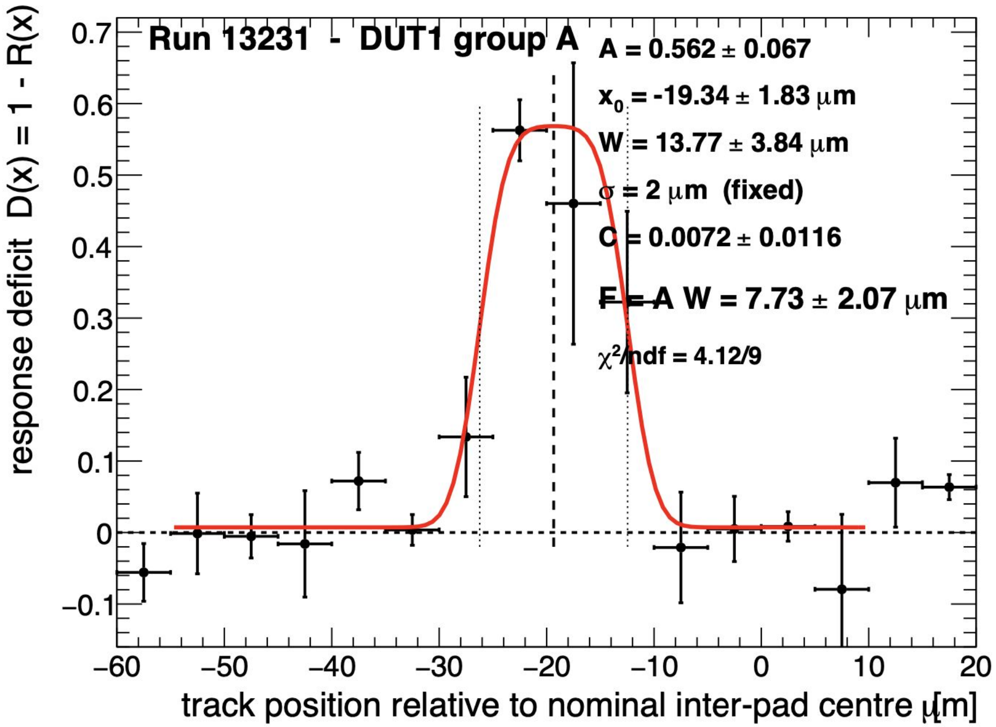
$$r_L(x) = \frac{S_L(x)}{S_{L,\text{bulk}}}, \qquad r_R(x) = \frac{S_R(x)}{S_{R,\text{bulk}}},$$

$$\boxed{R(x) = r_L(x) + r_R(x)}$$

$$\boxed{\eta(x) = \frac{r_R(x) - r_L(x)}{r_R(x) + r_L(x)}}$$

I normalize the integrated charge of each pad to its own bulk response. The sum R(x) tells me whether charge is actually lost, while η(x) tells me how the charge moves from one pad to the other.

Testing the concept for wafer 5 (II)

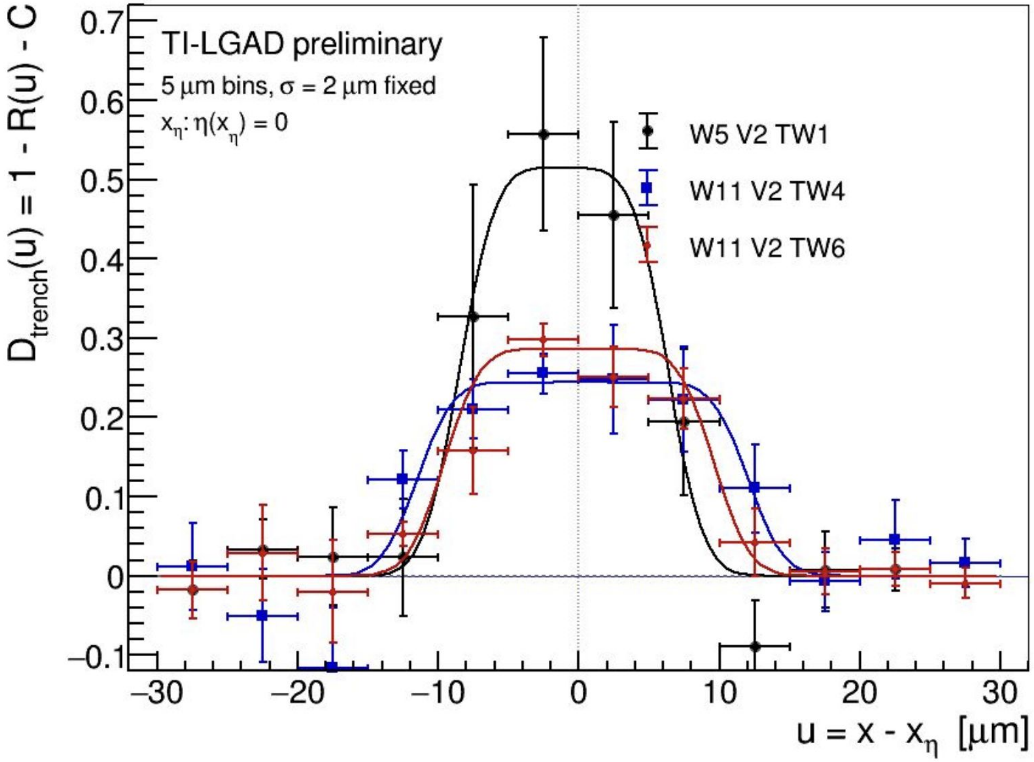


The baseline is consistent with zero, so this is a localized response deficit.
The fitted centre is x0=−19.3 μm, while the completely independent charge-sharing transition is around −19.7 μm

When I change the assumed edge smearing, A and W change substantially because they are correlated. But their product AW remains much more stable.

The double-erf fit gives F=7.73 μm, while directly integrating the measured response deficit gives about 7.8 μm. The agreement shows that AW is measuring the integrated response loss, rather than just being an arbitrary combination of fit parameters

Standardised TI-LGAD response-loss comparison



Common procedure

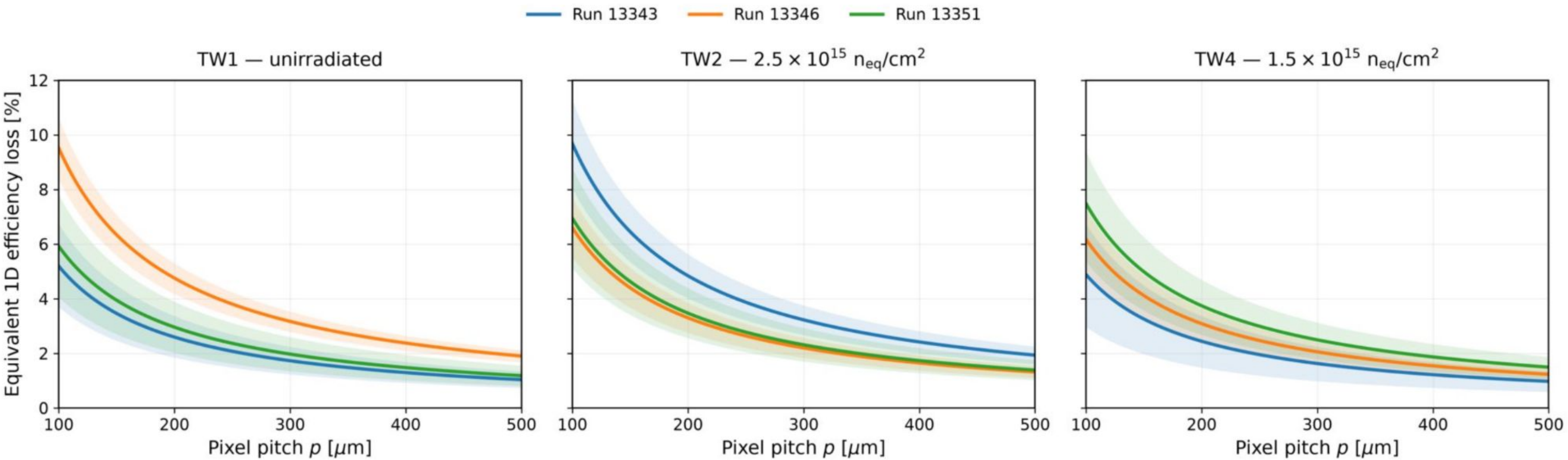
- Align each structure to the charge-sharing transition x_η:
  $\eta(x_\eta)=0$ $u=x-x_\eta$
- Same analysis for all structures: 5 μm bins,
  $|u|<30$ μm $\sigma=2$ μm
- The fitted response-loss centres are consistent with the charge-sharing centre:
  $u_0 \simeq 0$

$$F = AW = \int D_{\text{trench}}(u)\,du$$

$$\begin{aligned} \text{W5 TW1}: &\quad 7.66 \pm 1.92\ \mu\text{m} \\ \text{W11 TW4}: &\quad 5.85 \pm 1.13\ \mu\text{m} \\ \text{W11 TW6}: &\quad 5.42 \pm 0.66\ \mu\text{m} \end{aligned}$$

The fitted F=AW values are consistent with direct numerical integration, supporting F as a candidate common response-loss metric for TI-LGAD designs.

Equivalent inter-pixel efficiency loss vs pixel pitch



% on the y-axis is the estimated fraction of efficiency we lose because of the inter-pixel region

From measured inter-pixel efficiency to pitch impact

1 Measure ε(u)

Use the two-pixel efficiency profile across the inter-pixel boundary. The local reference efficiency comes from nearby sidebands.

$$\varepsilon(u) / \varepsilon_{local}$$

→

2 Integrate deficit

Convert the efficiency dip into an equivalent fully inefficient width.

$$w_{eff}^{\varepsilon} = \int [1 - \varepsilon(u)/\varepsilon_{local}]\, du$$

→

3 Scale to pitch

For one inter-pixel boundary per pitch, the equivalent 1D average loss is the effective width divided by the pitch.

$$L_{\varepsilon}(p) = w_{eff}^{\varepsilon} / p$$

Interpretation w_{eff}^{ε} is the width of an ideal zero-efficiency strip that would give the same integrated loss as the measured inter-pixel profile.

Quick numerical intuition

If $w_{eff}^{\varepsilon} = 5\ \mu m$: 5% at $p = 100\ \mu m$ • 2.5% at 200 μm • 1% at 500 μm

Extending the TI-LGAD parametrization to timing